

A physical dynamical
approach to monitoring
nutrient dynamics

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2D Model results: Courtesy of RMA

Proposal Title:

Development of a physical dynamical approach to monitoring nutrient dynamics at the landscape scale in the Sacramento San Joaquin Delta using a combination of fixed station and boat-based measurements

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Objective

- Develop a method for using the existing physical and chemical data collected in the Delta to estimate biogeochemical rates and evaluate how rates change under different conditions.
- The proposed approach leverages existing nutrient and water velocity time series, and existing field data collections.
- This work is intended as a proof-of-concept /feasibility study.

Approach

- Quantify the difference between the spatial distribution in nutrient concentrations that may be “expected” if nutrients were transported conservatively purely by advection (by the tidal currents), and the actual measured spatial distribution of nutrients.
- Estimated rates are the difference between the observed and expected concentration divided by the elapsed time.
- Permits evaluation of rates in complex tidal systems.

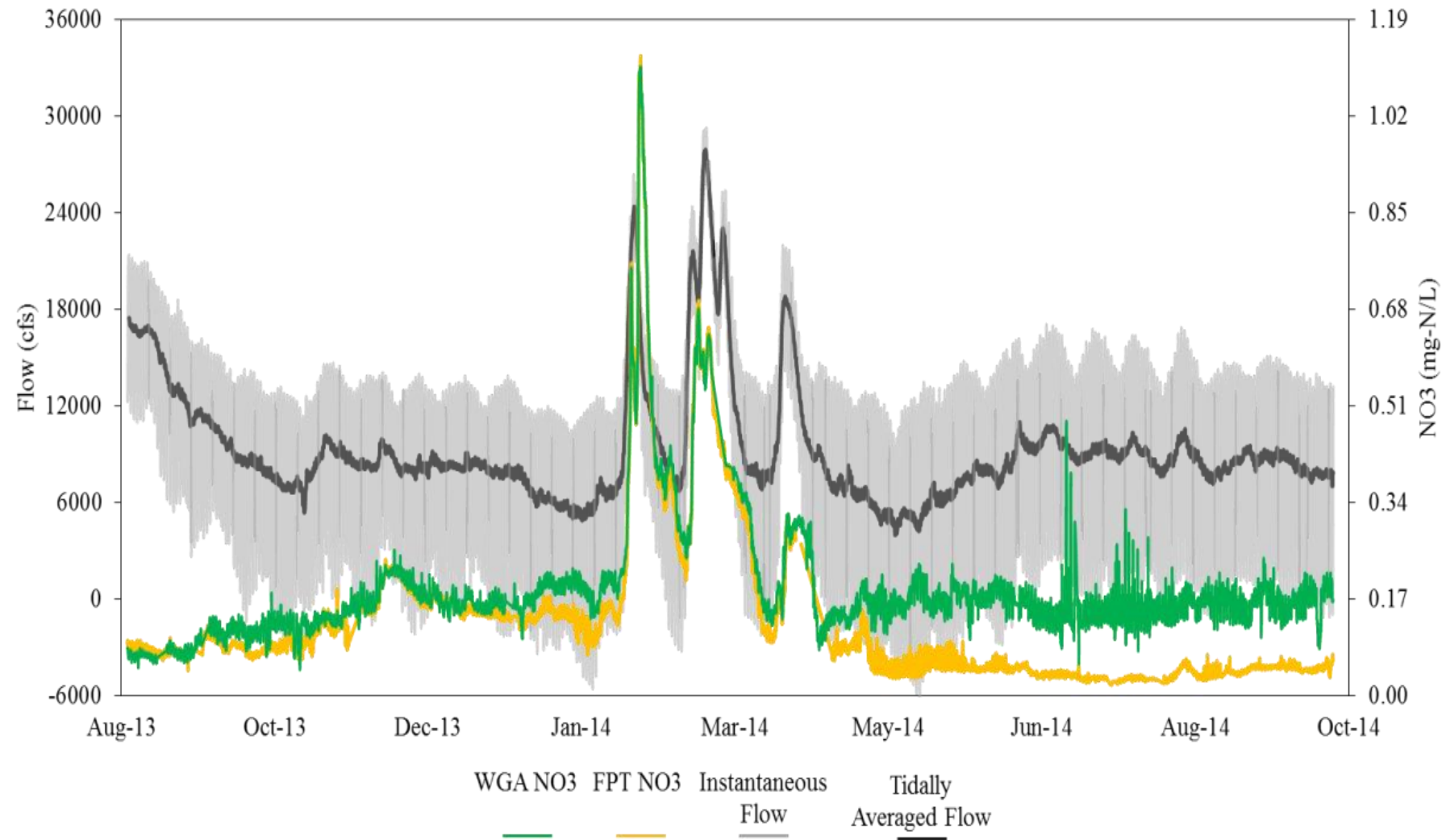
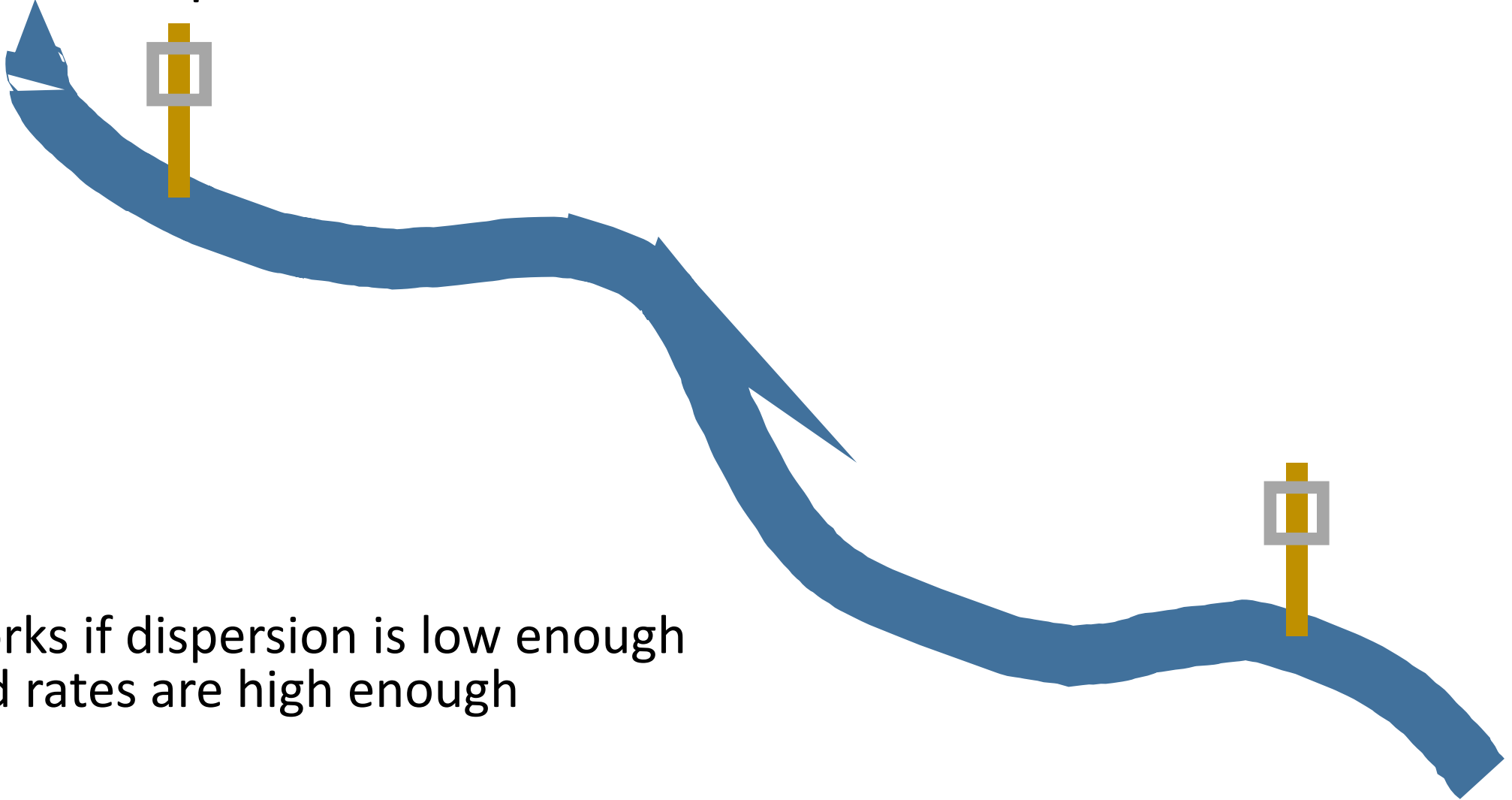


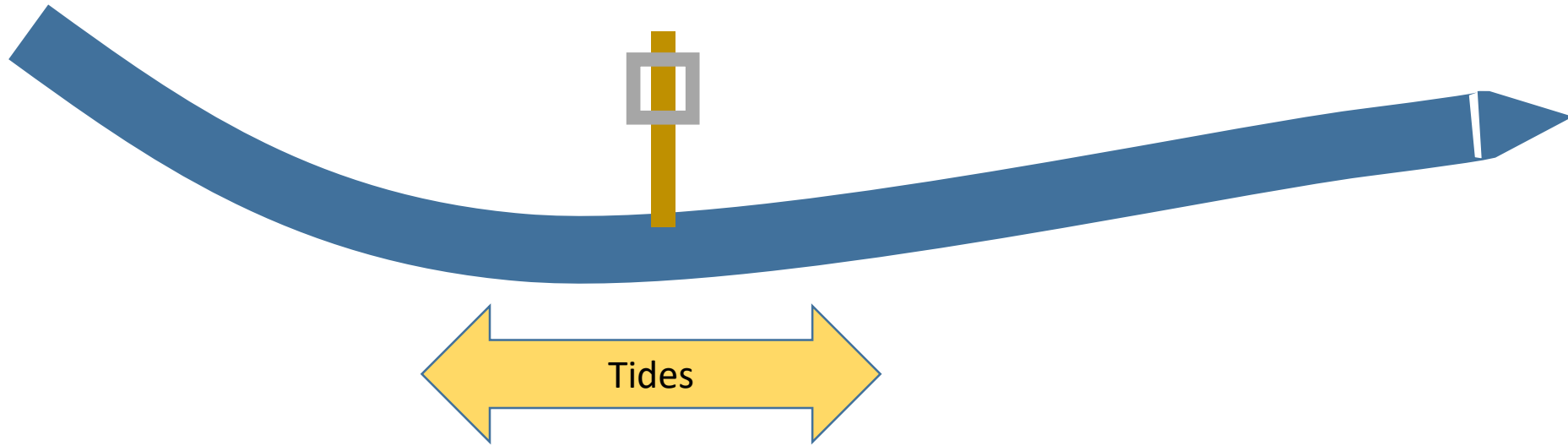
FIGURE 11. INSTANTANEOUS (GREY) AND TIDALLY AVERAGED (BLACK) FLOW OF THE SACRAMENTO RIVER AT FREEPORT (FPT) PLOTTED WITH NITRATE CONCENTRATIONS MEASURED AT THE CONTINUOUS MONITORING STATIONS LOCATED AT FPT (YELLOW) AND WALNUT GROVE (WGA, GREEN). FROM O'DONNELL, 2014.

Point to point



- Works if dispersion is low enough and rates are high enough

Slack to Slack



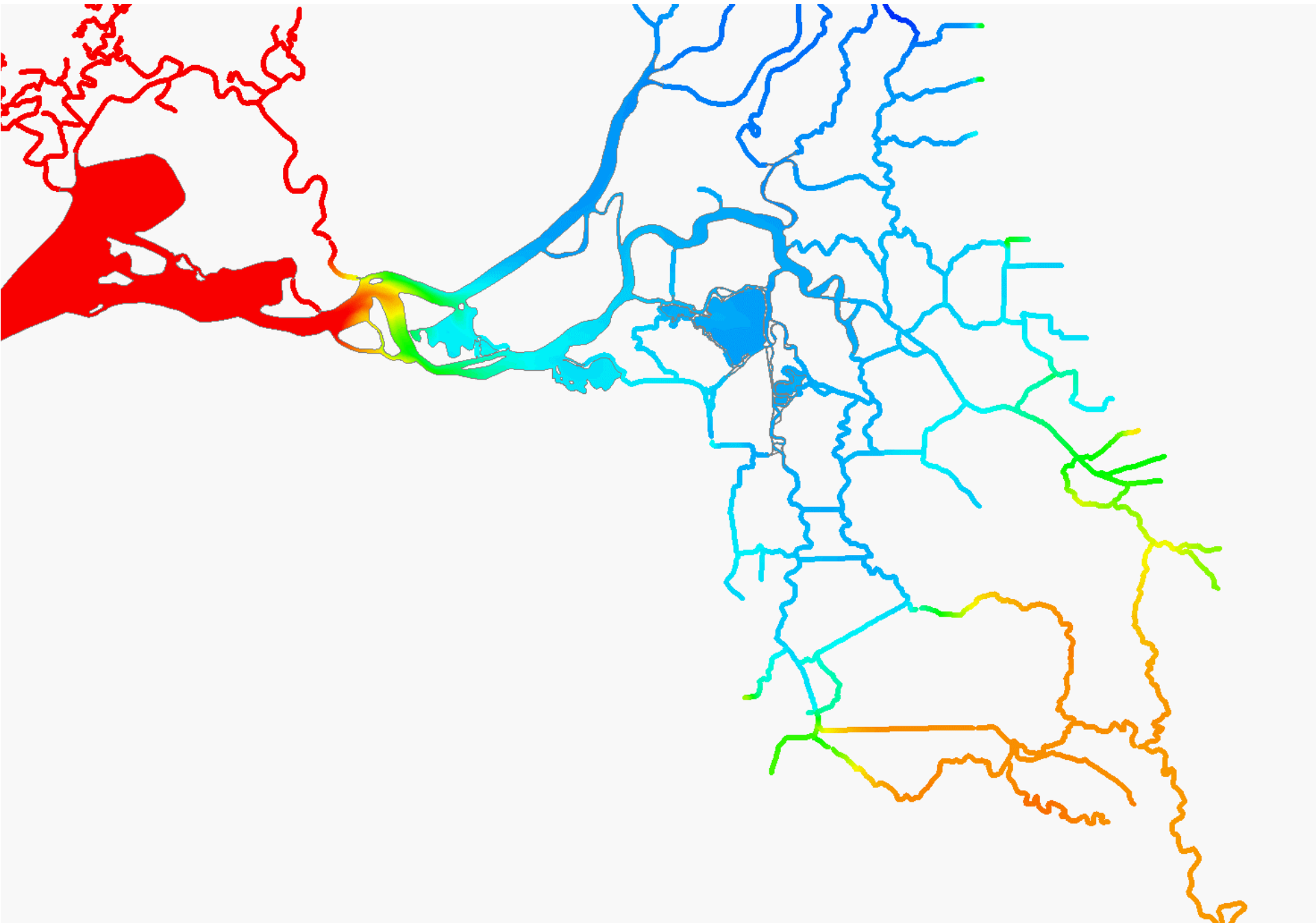
- Works if rates are large compared to tidal time scales

Constituent Tracker

**Estimating Spatial Distributions based on a
dense network of WQ/Flow stations and
simplified physics**

Bloom Tracker
(Chl-a, Nutrients)

Turbidity Tracker
Salinity Tracker
etc., etc.



2D Model results: Courtesy of RMA

Multistep Process to generate spatial maps of WQ constituents:

- (1) Linear interpolation between stations to a common point in **TIME** (Done: Bay/Delta Live)**
- (2) Linear interpolation to a common point in **TIDE** [slack after flood, slack after ebb]**
- (3) Assume pure advection – then correct for timing (advection) errors and dispersion using data assimilation**

Step (3)

Step 2: Scaling Analysis (assume pure advection then correct)

Better define gradients – common point in tide (slack water plots)

Use 1D adv-dispersion eq. - only has to apply for ½ tide cycle ~6 hours)

$$\frac{\partial c}{\partial t} = -u(e) \frac{\partial c}{\partial x} + D \frac{\partial^2 c}{\partial x^2} + \textcircled{S} \leftarrow$$

Step (1) assume pure advection (Eulerian)

$$\frac{\partial c}{\partial t} \approx -u(e) \frac{\partial c}{\partial x}$$

First order Euler/Lagrange transformation:
Wave Equation
(based on the simplified (1D) equations of motion)

$$\frac{\partial^2 \eta}{\partial t^2} = C_0 \frac{\partial^2 \eta}{\partial x^2} - \beta \frac{\partial \eta}{\partial t}$$

η = sea level variations referenced to the mean tide

$$\beta_n = \frac{8n^2 g U_n}{3\pi h_0^{4/3}}$$

n = Manning's friction coefficient

h_0 = mean depth

$$C_0 = \sqrt{gh_0}$$

g = gravity

$$K_n = \frac{2\pi}{\lambda} = \frac{\omega_n}{C_0}$$

λ = Wave length of a particular partial tide

ω_n = Frequency of partial tide

Solutions take the form:

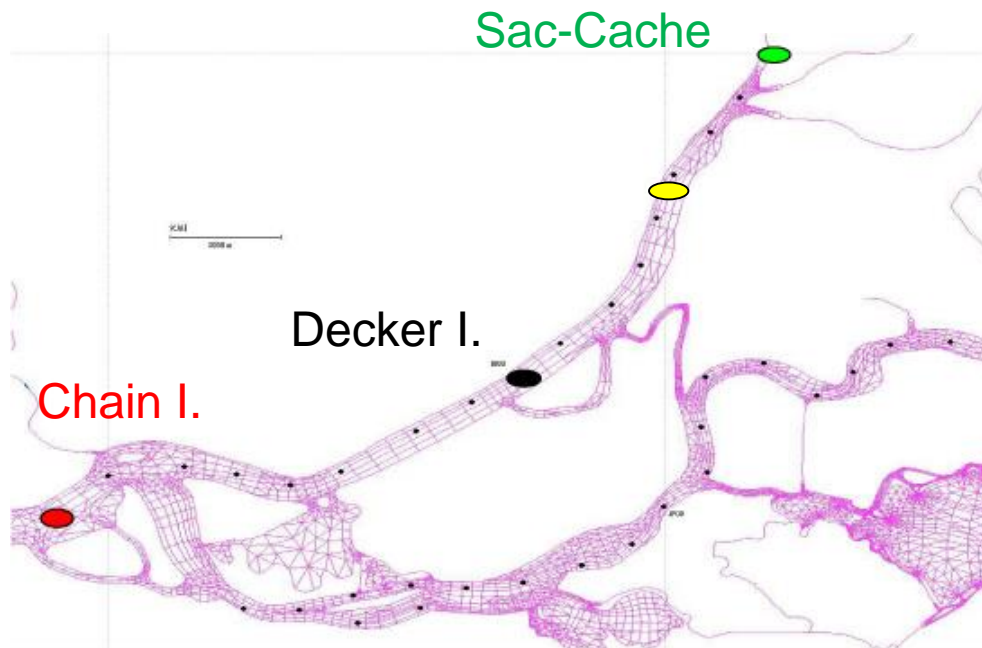
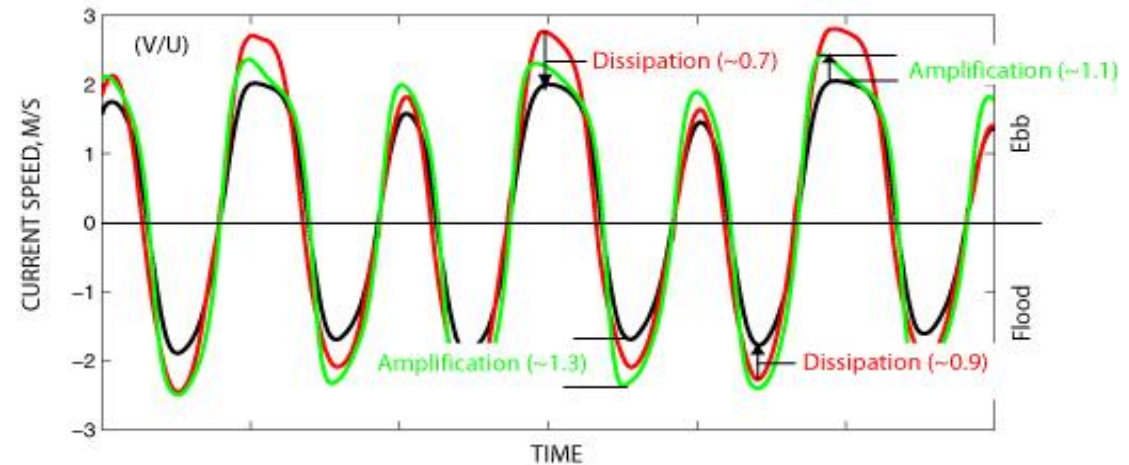
$$u = U(x_0, t)e^{-Ax} \cos(-Kx)$$

A, K = can be estimated using velocity data from adjacent stations

After Officer, 19xx

Euler-Lagrange Transformation Is critical for getting Advection between Stations right

Comparison of Velocities Along a Tidal Excursion Trajectory near Decker Island



Station Location
Sac-Cache Confluence - Upstream (Uu)
Decker Island - Fixed sampling location (V)
Chain Island - Downstream (Ud)

Often S is small compared to $-u(e)\frac{\partial c}{\partial x}$ and $D\frac{\partial^2 c}{\partial x^2}$
 – so to get at S we need to remove
 Variability associated with $-u(e)\frac{\partial c}{\partial x}$ and $D\frac{\partial^2 c}{\partial x^2}$

$$\frac{\partial c}{\partial t} = -\cancel{u(c)\frac{\partial c}{\partial x}} + D\cancel{\frac{\partial^2 c}{\partial x^2}} + \textcircled{S}$$

Generally in the Delta
Advection >>Dispersion>>Source/Sinks

$$-u(e)\frac{\partial c}{\partial x} \gg D\frac{\partial^2 c}{\partial x^2} \gg S$$

So we've taken care of advection
What do we do about dispersion

$$D\frac{\partial^2 c}{\partial x^2} \quad ???$$

First off because the Delta is made up of canals D is small

Bathymetric variability causes velocity shear -> causes dispersion – but we have little bathy variability in Delta



Courtesy of RMA

Lateral shear (minimal in canals) causes dispersion



Courtesy of RMA

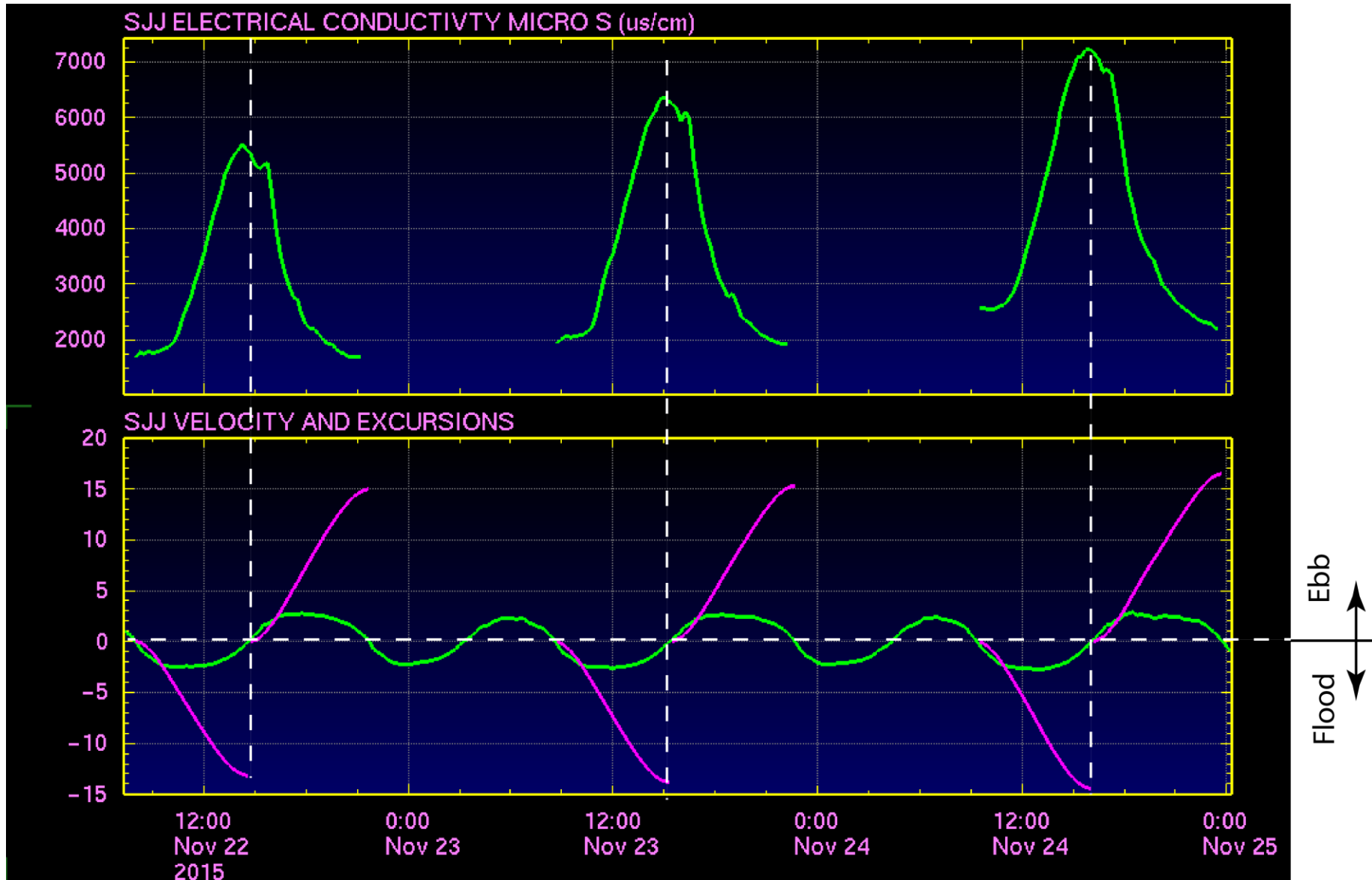
If we use a conservative tracer
Such as conductivity: Source/Sinks (S) = 0

We know advection (from above) so we can solve for D

$$D = [u(e) \frac{\partial c}{\partial x} - \frac{\partial c}{\partial t}] / \frac{\partial^2 c}{\partial x^2}$$

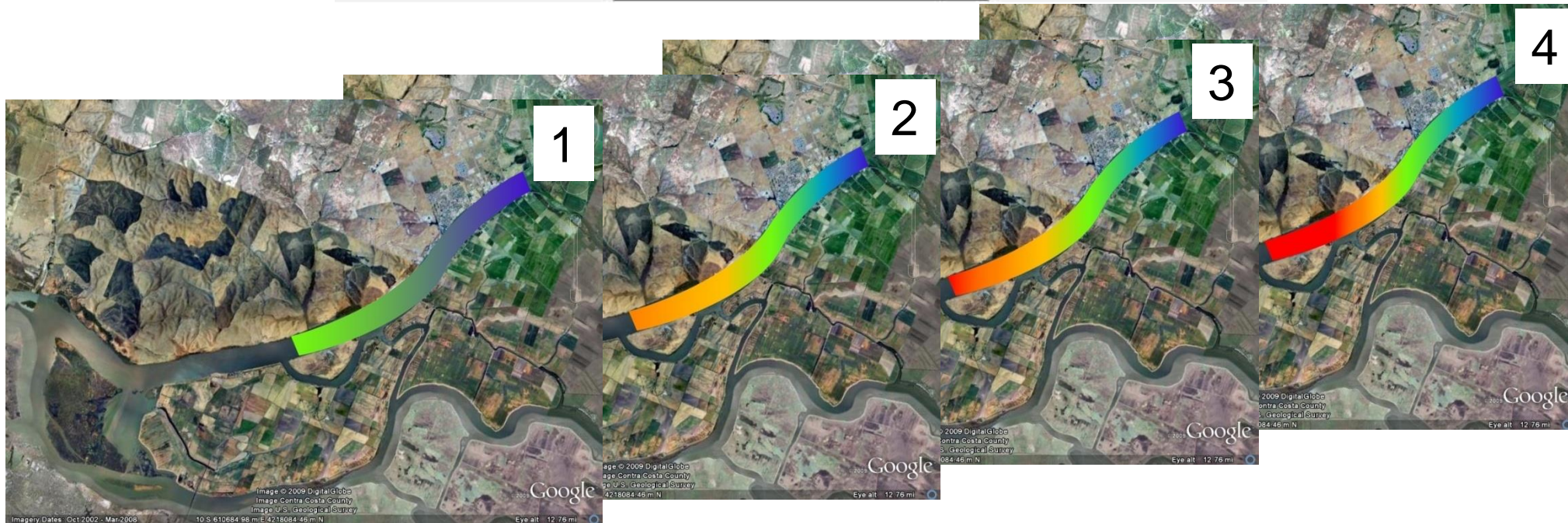
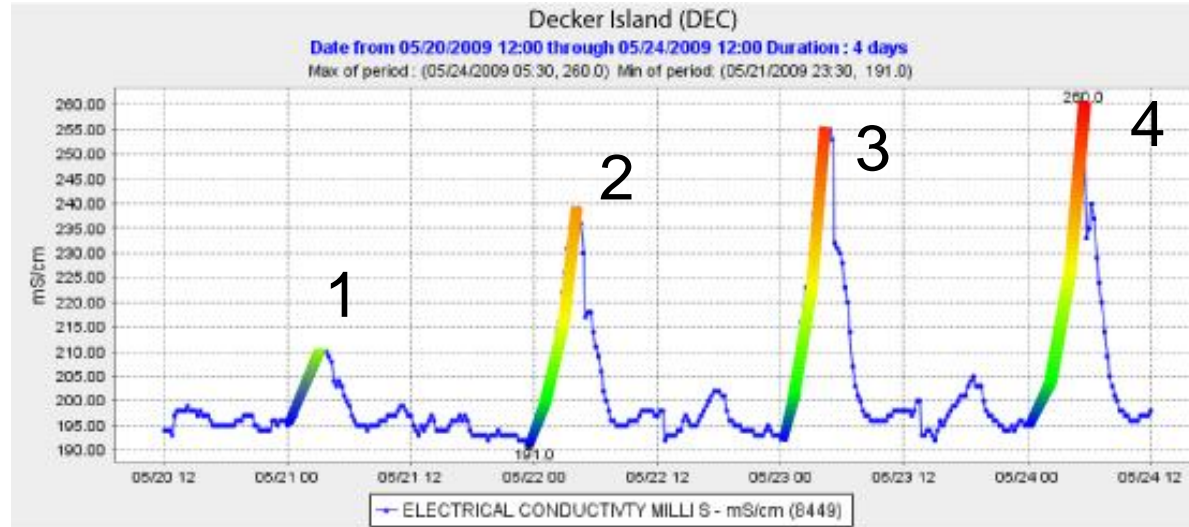
Assume D for conservative constituent
is the same for non-conservative constituent

Infer spatial structure by affiliating distance from station (advection)
with constituent measurements

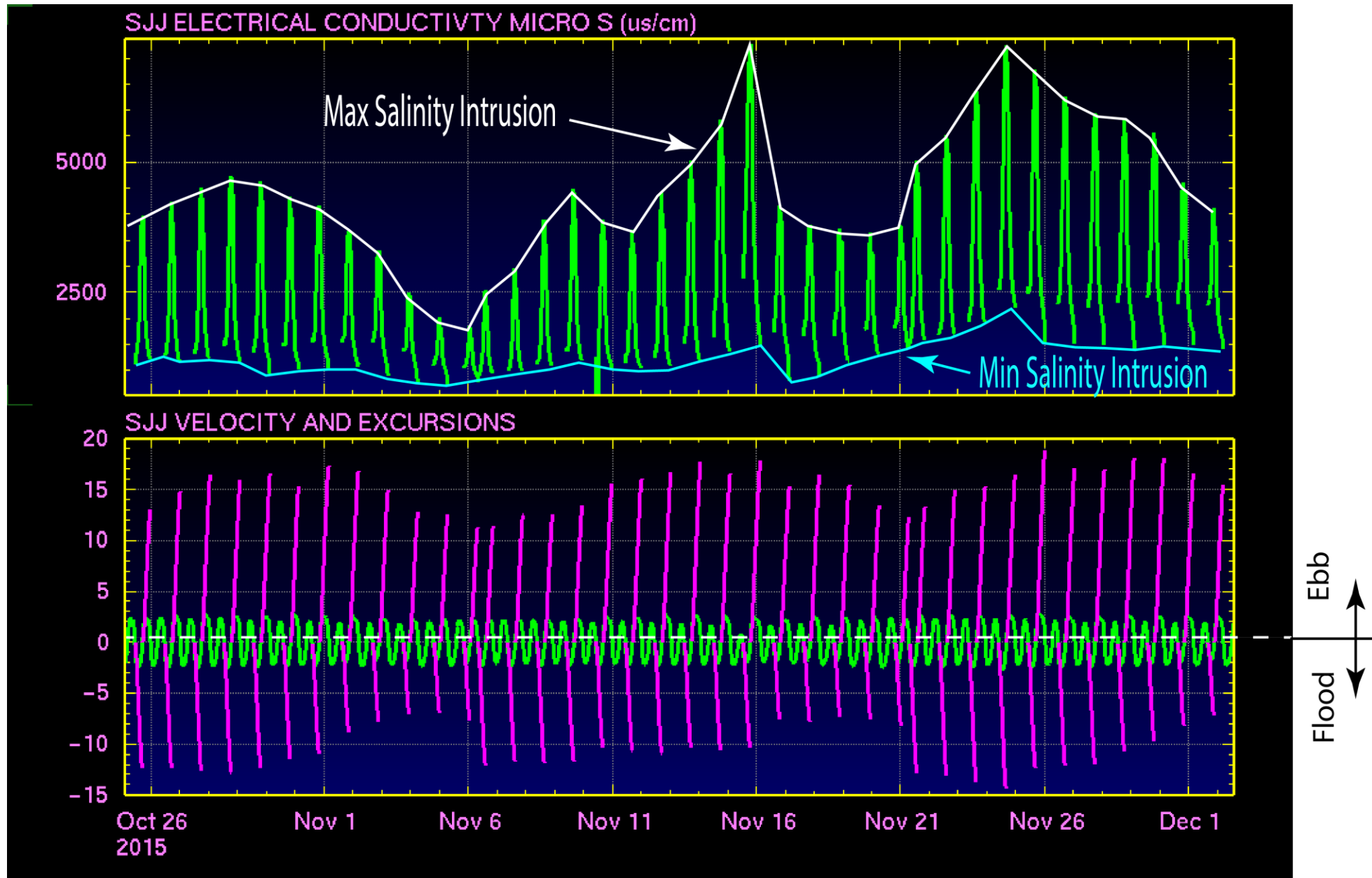


San Joaquin River at Jersey Point

A sequence of “Slack Water Plots” reveals temporal evolution of EC spatial structure within a tidal excursion of sampling location

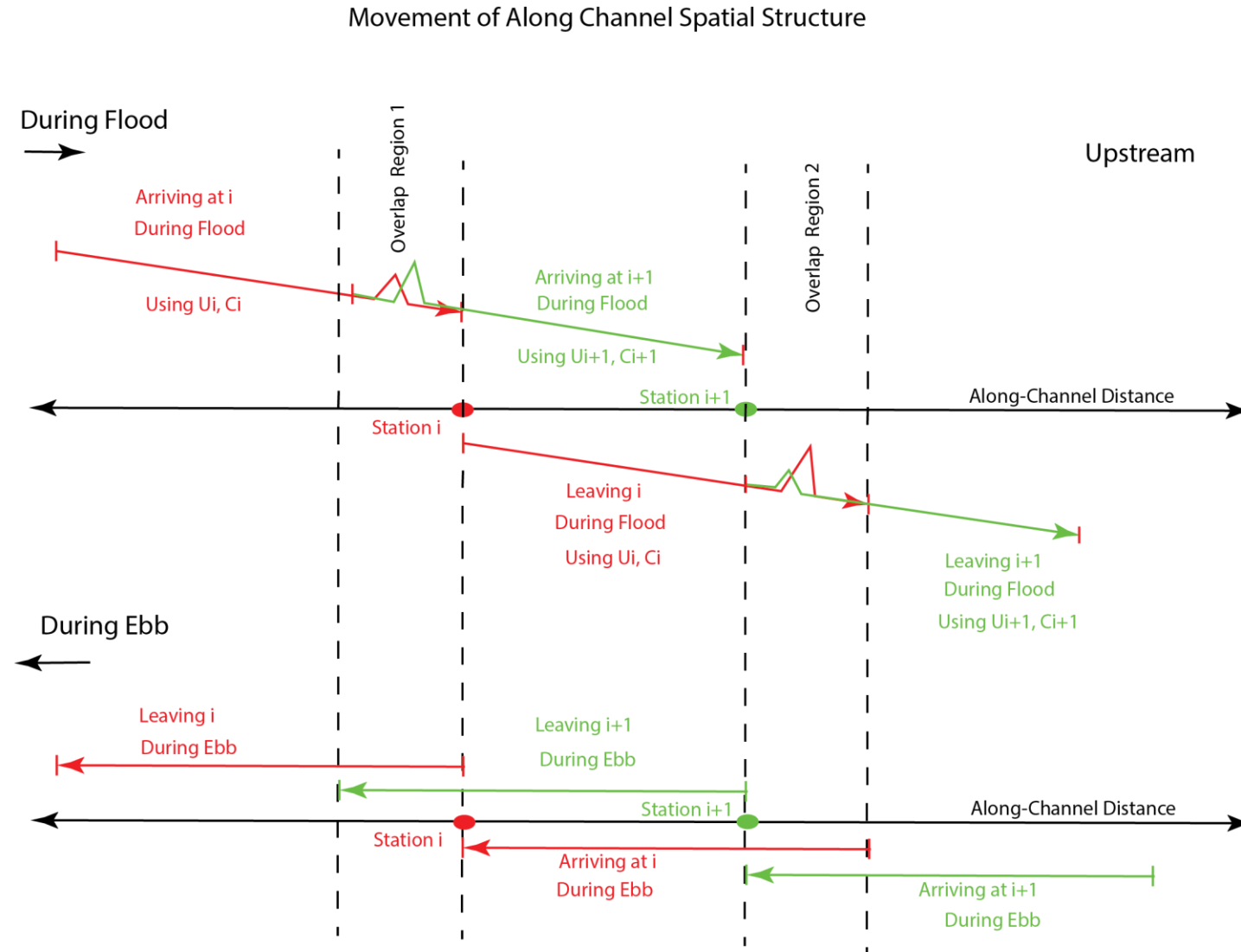


Spring/Neap Variability in Salinity Intrusion

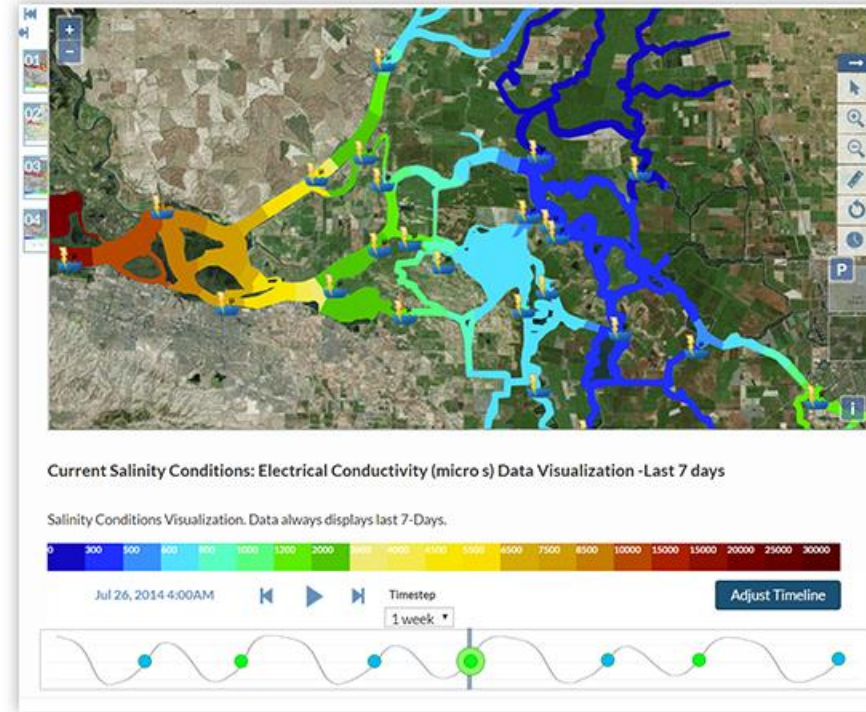
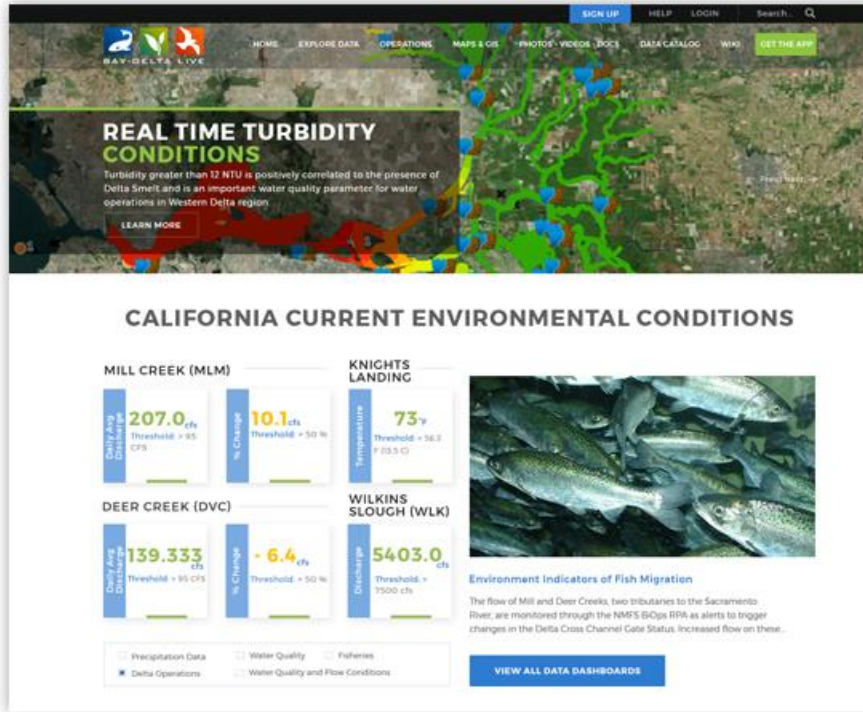


San Joaquin River at Jersey Point

Step 3: Use Overlap Region to correct for errors in spatial prediction from adjacent stations



Arrows represent tidal excursions - length of arrow represents distance travelled, arrow indicates direction of movement



Data Sets **Layers** **Sessions** **Menu**

Select Data Source

Data Source
CDEC (California Data Exchange)

[Explore!](#)

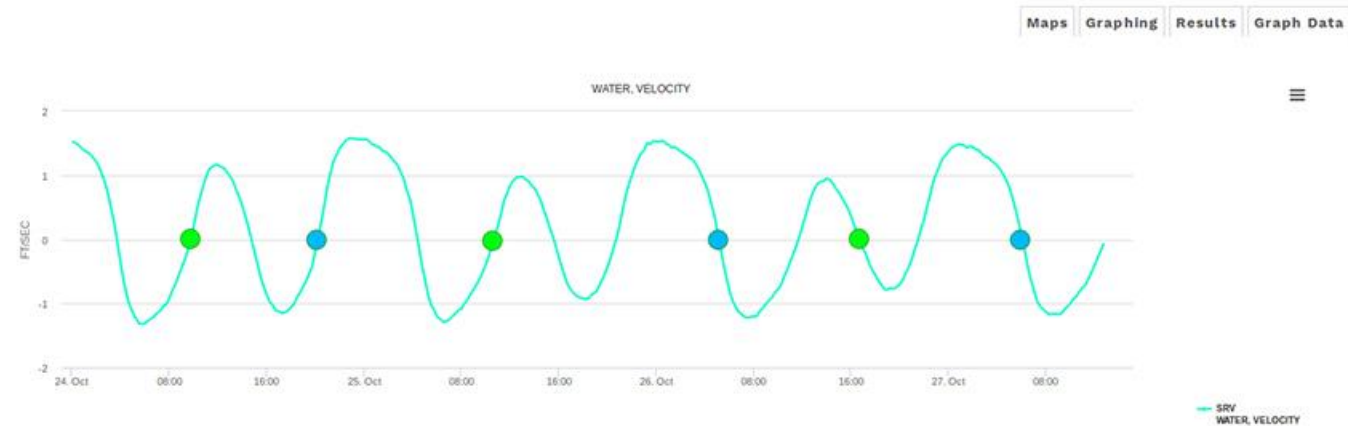
Date Interval

Start Date
2017-10-24

End Date
2017-10-27

Duration
3 Days

[Go!](#)



Questions?

Final Step

String all the slack after the “big” ebbs together to get the *net* movements of the constituent distributions when they are furthest into the bay.

String all the slack after the “big” floods together to get the *net* movements of the constituent distributions when they are furthest into the delta.

Three ways to do this

- Point to point
- Slack to slack at a given point
- Slack-tide surface compared to actual measured surface

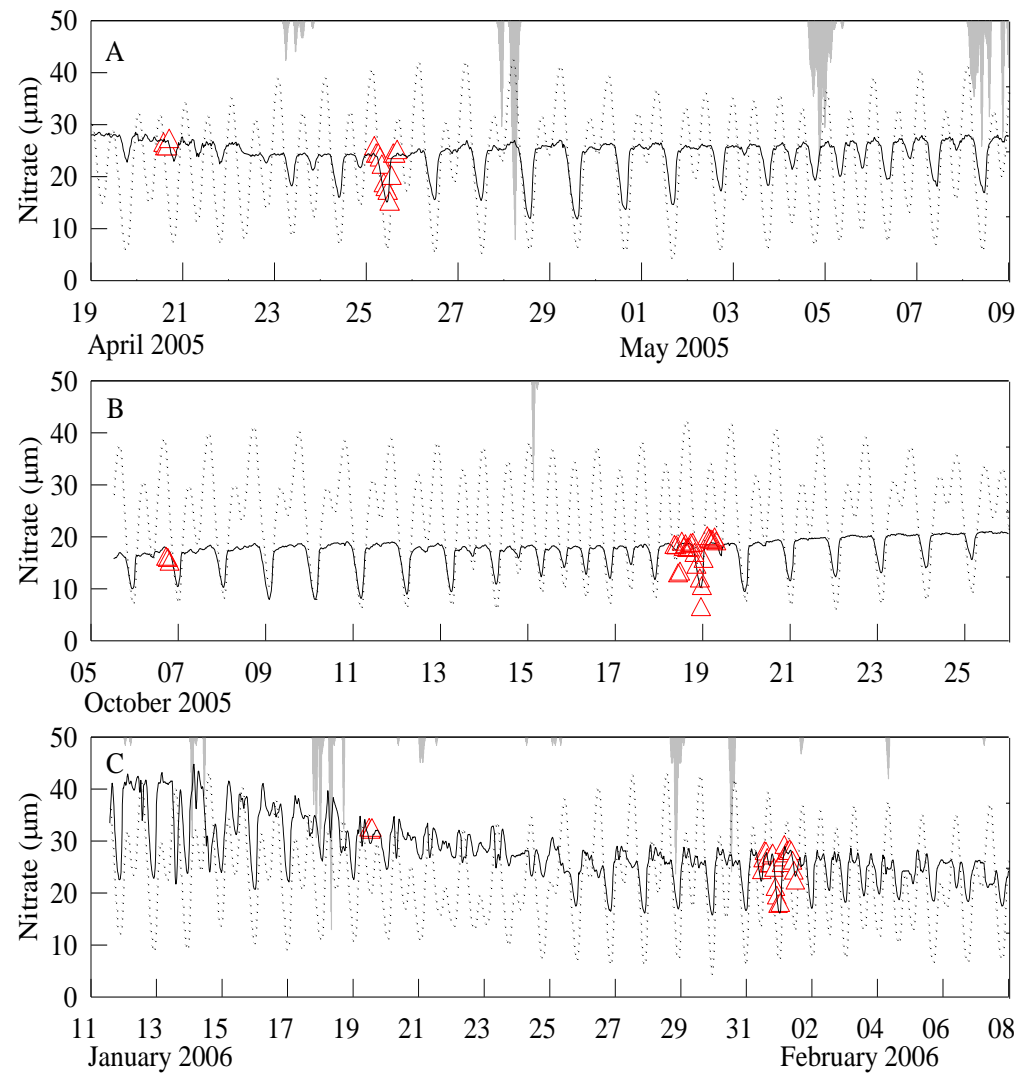
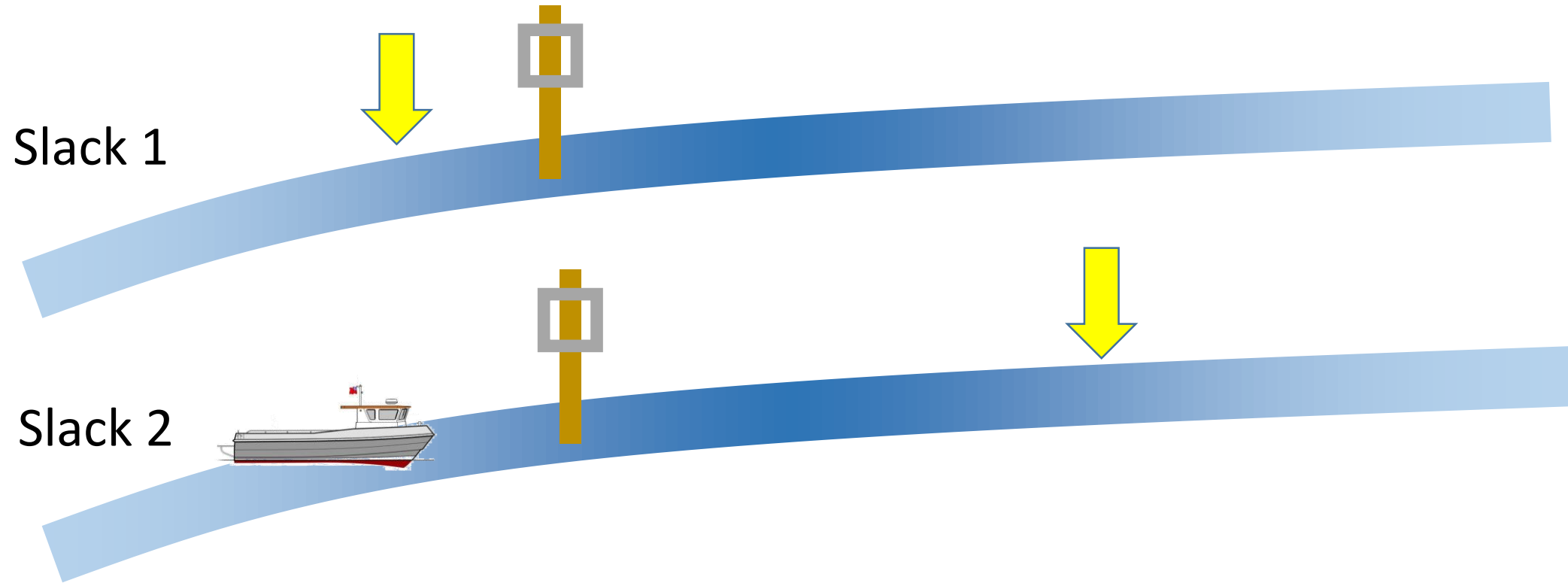
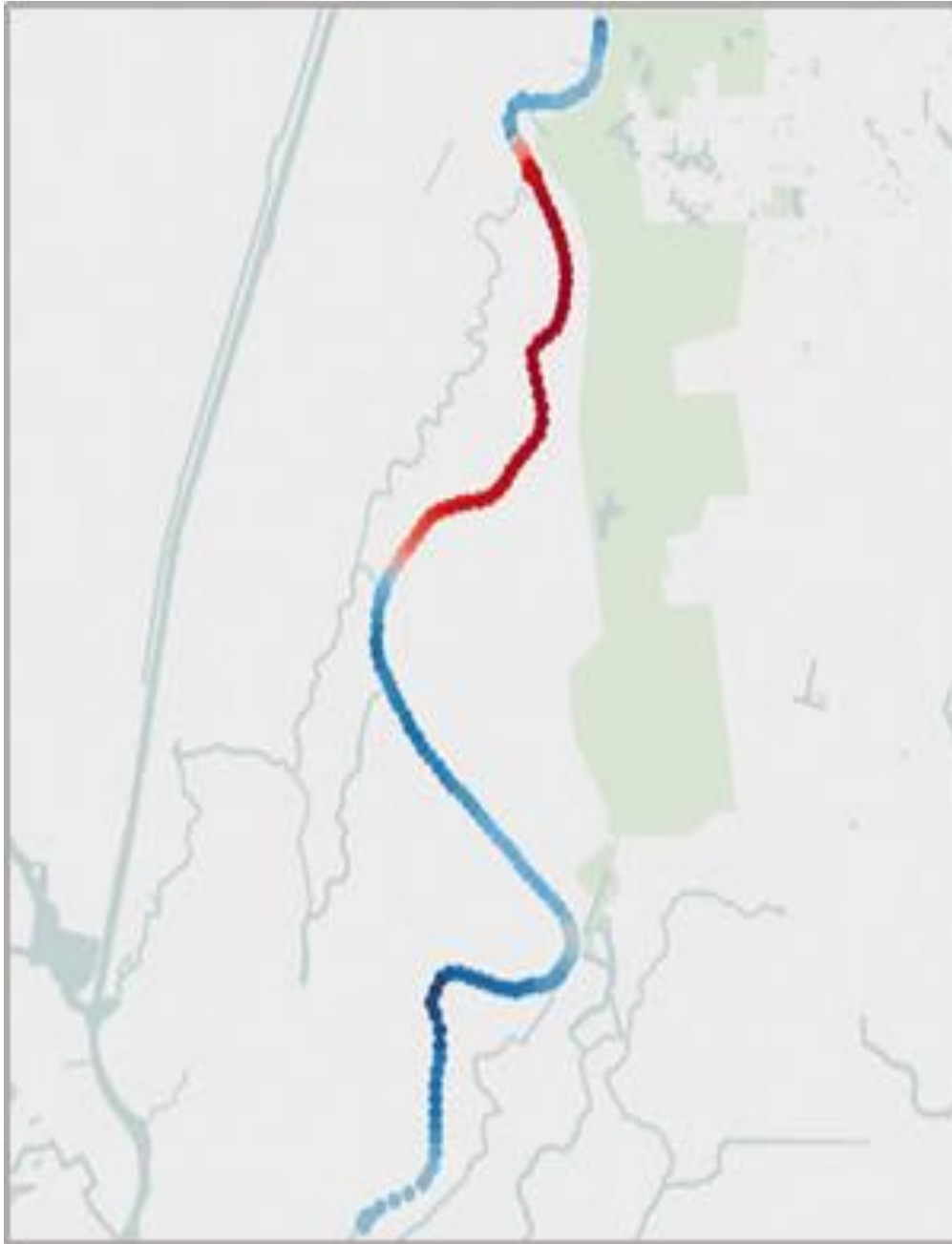


FIGURE 9 TIME SERIES OF NITRATE (NO_3) CONCENTRATION DATA COLLECTED AT BROWN'S ISLAND IN 2005 AND 2006 PLOTTED WITH STAGE (DASHED LINE), PRECIPITATION (GREY BARS), AND GRAB SAMPLE CALIBRATION DATA (RED TRIANGLES). THREE DIFFERENT DEPLOYMENT PERIODS ARE SHOWN: (A) APRIL/MAY 2005, (B) OCTOBER 2005, (C) JANUARY/FEBRUARY 2006.

Slack water surface



- Works for slower rates



*FIGURE 14 MAP OF DATA
GENERATED BY AN IN SITU
FLUOROMETER DESIGNED TO
DETECT DISSOLVED ORGANIC
MATTER (FDOM) COLLECTED
ALONG A SECTION OF THE
SACRAMENTO RIVER SHOWING
THE ABILITY TO MAP THE
PRESENCE (BLUE) AND
ABSENCE (RED) OF
WASTEWATER EFFLUENT.*

Need to sort out the physics

- Advection, dispersion and all that sort of crap
- Equations and graphs
- Animations and arm waving

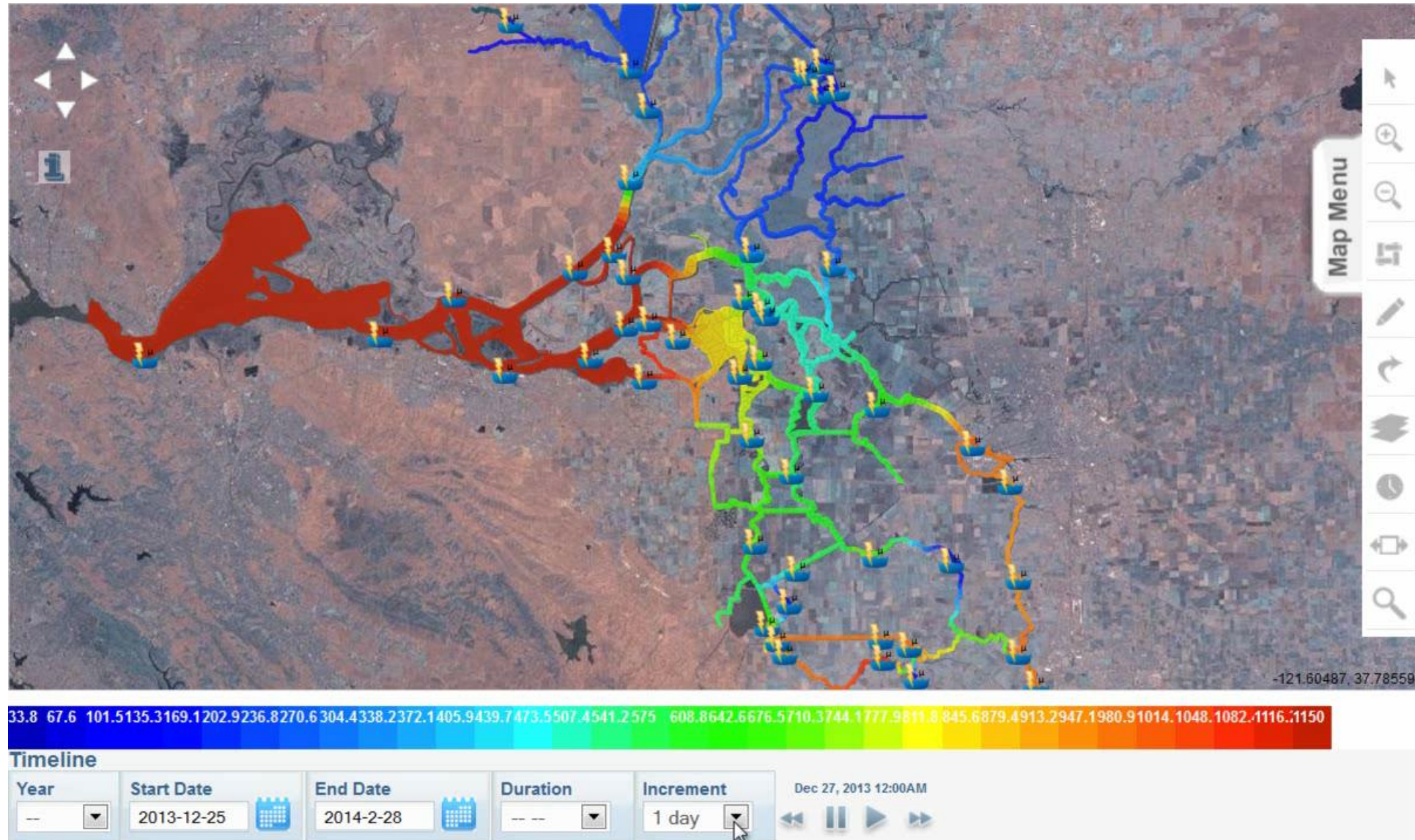
Step (1)

Step 1: Linear Interpolation -constant point in *time*
(We already have this! Bay/Delta Live)

(a) Tidal timescale: spatial maps based on linear interpolation between stations every 15 minutes, hourly, etc.

Good for big picture, but no gradients between stations – linear interpolation

Linearly Interpolated Turbidity Field –Constant Point in Time: Courtesy of 34North



Step (2)

Step 2: Linear Interpolation -constant point in *tide*

(b) Net (or residual timescale):

Linearly interpolate to a constant point in tide (say slack after flood and ebb each day) – string together to get the big picture movements of constituent field

Good for big picture, but no gradients between stations – linear interpolation